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TITLE: Autostereoscopic video device

Abstract Text (1):
The invention relates to a single-camera autostereoscopic picture-taking device implementing an array of cylindrical lenses, characterized in that it comprises in succession:

Abstract Text (3):
said lens array (20), which has a focal length such that for an image area equal to the pitch (p) of the lenses making it up, the image of the entrance pupil of the telecentric objective (L1, L2) has a nominal width equal to said pitch;

Abstract Text (4):
a transfer optical system (L3, L4) having magnification of less than unity; and

Abstract Text (5):
an image sensor (22),

Abstract Text (6):
the transfer optical system (L3, L4) directing the light rays that emerge from the lens array (20) onto the image sensor (22), the image (21) of the lens array (20) in the transfer optical system (L3, L4) being such that the pitch (p) of the lenses of the lens array (20) corresponds therein to an integer number of image points (pixels) of the image sensor (22).

Brief Summary Text (1):
The present invention relates to a single-camera autostereoscopic video device implementing an array of cylindrical lenses.

Brief Summary Text (2):
United States patent U.S. Pat. No. 3,932,699 discloses an autostereoscopic picture-taking device having an array of lenses on which light rays from an object are focused, the lens array being placed against a window that is sensitive to light and constitutes part of a Vidicon tube, for example.

Brief Summary Text (4):
A much more elaborate stereoscopic picture-taking device was proposed by McCormick et al. at the stereoscopic television colloquium that was held in London on Oct. 15, 1992. He proposed taking stereoscopic video pictures by recording an image that is projected onto a diffusing screen by two autocollimated lens arrays. That device suffers from the drawback of considerable complexity and in particular the use of three lens arrays that must be in perfect alignment otherwise the image is affected by extremely troublesome moire phenomena.

Brief Summary Text (6):
French patent FR 1 362 617 (Yariaonkine) relates to a picture-taking device having a plurality of entrance objectives, specifically two lenses, each having its own optical axis, thus providing two entrance objectives with two optical axes corresponding to respective viewpoints. To obtain a composite image with interlacing, a frosted screen is placed on the plane face of the plate 7 and the screen is scanned horizontally by a normal camera. The screen gives rise to losses of light intensity and of contrast. In addition, given that the microlenses of the array 7 must have a field angle enabling them to see both objective lenses, certain

light rays are very highly inclined relative to the optical axis, thus giving rise to problems of vignetting.

Brief Summary Text (7):
The idea on which the invention is based is to implement a single entrance objective, on a single optical axis, while still making it possible without a frosted screen to obtain an autostereoscopic image having two or more viewpoints. To this end, the invention provides a single-camera autostereoscopic picture-taking device implementing an array of cylindrical lenses, characterized in that it comprises in succession:

Brief Summary Text (9):
b) said lens array is disposed substantially in the image focal plane of the entrance objective, said array having a focal length such that for an image area equal to the pitch of the lenses making it up, the image of the entrance pupil of the entrance objective has a nominal width equal to said pitch;

Brief Summary Text (10):
c) a transfer optical system having magnification of less than unity; and

Brief Summary Text (11):
d) an image sensor,

Brief Summary Text (12):
the transfer optical system directing the light rays that emerge from the lens array onto the image sensor, the image of the lens array in the transfer optical system being such that.the pitch of the lenses of the lens array corresponds therein to an integer number of image points (pixels) of the image sensor, and the image of the pupil of the entrance objective, in the absence of the lens array, being situated substantially at the pupil of the transfer optical system.

Brief Summary Text (13):
Because of its orthoscopic transfer optical system, this device makes it possible, in particular, to conserve a stereoscopic baseline corresponding to the inlet pupil diameter of the entrance objective, in spite of the reduction in the format of the image on the sensor. In addition, the picture-taking device of the invention uses only one lens array, which is particularly favorable for optical quality.

Brief Summary Text (14):
The image sensor may be a charge-coupled type of sensor, and it is preferably constituted by a set of three individual sensors associated with a prismatic three-color beam-splitter forming images on the three sensors, which images that are nominally in mutual alignment, image point by image point. This makes it possible to obtain a high degree of separation between viewpoints without having to subdivide the inlet pupil into as many sub-pupils.

Brief Summary Text (15):
Optimum separation between viewpoints is obtained by orienting the lens array in the line direction of the image sensor. It may be observed that this orientation corresponds to rotation through 90.degree. relative to the normal position, given that the orientation of a lens array must be such as to provide horizontal separation between the viewpoints.

Brief Summary Text (16):
The entrance objective may include an inlet lens whose pupil is substantially equal to 100 mm.

Brief Summary Text (17):
The pitch of the lens array may be 0.4 mm.

Brief Summary Text (18):
The transfer optical system may advantageously have magnification that is substantially equal to 0.1.

Brief Summary Text (24):

In a second aspect, the invention relates to a method of transmitting and/or recording a stereoscopic image, in particular using a single camera and implemented by means of an array of cylindrical lenses.

Brief Summary Text (29):
To this end, in the second aspect, the invention provides a method of transferring single camera autostereoscopic images obtained by means of an array of cylindrical lenses, characterized in that it includes a step of making a transcoded image of said autostereoscopic image, such a transcoded image comprising a plurality of flat images of anamorphosed format equal in number to the number of stereoscopic viewpoints, the flat images of anamorphosed format being placed side by side, the transcoded image being subjected to said transfer, i.e. to transmission and/or recording.

Brief Summary Text (40):
In a preferred embodiment, the transformation operations are performed by direct transcoding in the image sensor of the camera, which sensor is provided with a transcoding matrix, the matrix being preferably disposed between the columns of image points (or pixels) and a line shift register.

Brief Summary Text (48):
It comprises a first array of cylindrical lenses upstream from a diffusing screen, and a second array of cylindrical lenses downstream from the diffusing screen.

Brief Summary Text (49):
Each cylindrical lens of the first lens array corresponds to a number of vertical lines equal to the number of viewpoints of the stereoscopic image. Such an image as formed in this way on the diffusing (frosted) screen is transferred in conventional manner by the second array.

Brief Summary Text (53):
As a result, the highest frequency of the image is associated with the array and is significantly higher than the initial pixel frequency, and, when at the selected nominal observation distance, the spectator sees with each eye and through the first lens array, only a single viewpoint (without moire fringes).

Brief Summary Text (54):
The first cylindrical array may be a parallax barrier or a lens array.

Brief Summary Text (56):
The projection apparatus of the invention may comprise a conversion device for transforming a transcoded image comprising a plurality of flat images of anamorphosed format equal in number to the number of viewpoints and disposed side by side into a plurality of said deanamorphosed elementary images, and in that the conversion device has outlets for said elementary images, which outlets are coupled to respective inlets of video projectors. In a preferred embodiment, the conversion device may include an interpolator device such that the flat images are deanamorphosed with interposition of intermediate pixels, e.g. calculated by interpolation, so as to increase the resolution of the image.

Drawing Description Text (18):
FIG. 17 is a table corresponding to an inlet for N image mode in pixels at a pitch of 4 and with an outlet in relief mode for the same circumstances, to provide an output with inverted relief;

Drawing Description Text (28):
FIG. 26 shows an output module enabling the projection device of FIG. 25 to be fed with flat images of anamorphosed format and with intermediate pixels being interposed to increase resolution;

Detailed Description Text (1):
As shown in the above analysis of the prior art, there are at present two main ways of obtaining autostereoscopic images, one of which (U.S. Pat. No. 3,932,699) implements a lens array adjacent to a video camera, and the other of which is much more elaborate and projects an image filmed by a conventional video camera onto a

diffusing screen.

Detailed Description Text (2):
In FIG. 1, a picture-taking device of U.S. Pat. No. 3,932,699 comprises a camera 10 which is associated with an objective 9 having a mean plane 9'. A point 2 of an object 1 to be displayed emits rays 3 and 4 that are received by the full aperture of the lens 9. In the same manner, each point 9" receives light from all of the points of the object 1 (extreme received and re-emitted rays 5 and 6). The lens 9 is a converging lens placed in front of a radiation-sensitive surface 8 of the camera 10. The camera may be a Vidicon tube receiver, for example. A dispersing element 7, in particular a lens array adjacent to the photosensitive element makes it possible to achieve a plurality of elementary images of the scene to be filmed in a manner that is spatially repetitive, thereby enabling the camera 10 to transmit stereoscopic image information. The inlet surface of each elementary lens making up the lens array 7 is cylindrical in section about a vertical axis, while the outlet surface of each lens element is plane. As mentioned above, this picture-taking device presents major geometrical aberrations because of the need for the optical system to have a very large aperture in order to conserve an adequate stereoscopic baseline. In addition, a lens array having the dimensions of a standard video sensor is very difficult to make, particularly since its focal length must be very short (of the order of 100 microns, which is almost incompatible with any practical implementation).

Detailed Description Text (3):
The stereoscopic television system proposed by McCormick et al. at the colloquium on stereoscopic television (London, Oct. 15, 1992) and which is summarized in the article "Restricted parallax images for 3D TV" takes pictures in the manner shown in FIG. 2. It comprises an autocollimating transmission screen 12 having two adjacent arrays of cylindrical lenses 11 and 13, and a lens L' at whose focus there is placed a screen that is made up of a third array of cylindrical lenses 14 and a frosted screen 15. The stereoscopic image formed on the frosted screen 15 is transferred by an optical system 16 and projected in reduced form onto the sensitive portion 18 of a detector 19, e.g. a Vidicon tube. The concept of that system is to use a video camera (16, 18, 19) to take a picture in conventional manner of an image projected on a screen. That picture-taking device is very complicated since it uses at least three arrays of cylindrical lenses which must be accurately positioned geometrically relative to one another, and it also uses projection onto a diffusing screen, thus giving rise to losses of light efficiency, of resolution, and of contrast. Such a device is also sensitive to mechanical vibration and to temperature variation, both of which phenomena are liable to give rise very quickly to moire patterns that are most disagreeable in appearance and that considerably degrade the stereoscopic information.

Detailed Description Text (5):
1) An entrance objective that is preferably elecentric, comprising an inlet lens L.sub.1 and an outlet lens L.sub.2 whose focus F.sub.2, in a telecentric system, coincides with the optical center O.sub.1 of the lens L.sub.1. Such an entrance objective is known per se from European patent application EP-A-O 84998 (CNRS). When an optical system is telecentric, the image of the central point of the inlet pupil of the lens L, is sent to infinity by the lens L.sub.2, thereby giving rise to parallelism making it possible to engage the lens array in favorable manner. In particular, the two lenses L.sub.1 and L.sub.2 may be conjugate, i.e. the focus F.sub.1 of the lens L.sub.1 may also coincide with the optical center O.sub.2 of the lens L.sub.2. By way of example, the objective L.sub.1 may have a focal length of 200 mm and an aperture of f/2, which corresponds to a working pupil diameter of 100 mm, which distance constitutes the available stereoscopic baseline for taking pictures. This value which is significantly greater than the spacing between the eyes of an observer (or inter-pupil distance, which is about 65 mm), is particularly favorable for achieving realistic stereoscopic perspective after projection on a screen.

Detailed Description Text (6):
2) A lens array having an area of about 70 mm.times.90 mm made up of elementary lenses disposed vertically and having a pitch p of 0.4 mm and disposed substantially in the focal plane of the entrance objective (in practice very slightly downstream

therefrom). Each of the elementary lenses has a focal length such that, for an image area equal to the pitch E of a microlens, i.e. 0.4 mm wide, the image of the pupil of the objective F.sub.1 formed through each of the elementary lenses is exactly 0.4 mm. This makes it possible for all of the pupil images formed by each elementary lens (or microlens) to touch one anther exactly. It may be observed that since the array 20 is made up of cylindrical type lenses, the dimensions of pupil images are naturally to be considered in the horizontal plane.

Detailed Description Text (7):
3) A transfer optical system which is preferably orthoscopic, i.e. which does not induce vertical line deformations, and possibly comprising a field lens L.sub.3 positioned downstream from the lens array 20 to send all of the light rays from the array 20 towards an image transfer objective L.sub.4. The objective L.sub.4, e.g. having a focal length of 25 mm, is mounted on a camera 22 provided with charge-coupled sensors. This transfer optical system L.sub.3, L.sub.4 forms a real image 21 of the lens array 20 immediately upstream from the sensors of the camera 22. The magnification of the transfer optical system L.sub.3, L.sub.4 is selected so that rays emerging from the lens array 20 are sent to the camera 22 under conditions such that the image 21 has a pitch p' corresponding to an integer number of image points (pixels) of the image sensor 22. In addition, the distance between the image 21 and the image sensor 22 is such that focusing takes place on the sensor(s) of the camera 22.

Detailed Description Text (8):
The elements of the entrance objective and of the transfer optical system are disposed in such a manner that in the absence of the lens array, the image of the pupil of the entrance objective coincides substantially with the pupil of the transfer optical system. This condition ensures, in particular, that when the entrance objective is not telecentric, the transfer optical system restores parallelism in a manner described below.

Detailed Description Text (12):
A lens array 20 having a pitch of 0.4 mm and a focal length of 1.66 mm was disposed 20 mm from the optical center of L.sub.2 and at 90 mm from the optical center of L.sub.3. The lens L.sub.1 was constituted by a doublet L'.sub.1, L'.sub.2. Its pupil is written P.sub.1.

Detailed Description Text (13):
distance O.sub.1 O.sub.2 between the optical centers of the lenses L.sub.1 and L.sub.2 : O.sub.1 O.sub.2 =180 mm

Detailed Description Text (14):
distance O.sub.2 O.sub.3 between the optical centers of the lenses L.sub.2 and L.sub.3 : O.sub.2 O.sub.3 =110 mm

Detailed Description Text (15):
distance O.sub.3 O.sub.4 between the optical centers of the lenses L.sub.3 and L.sub.4 : O.sub.3 O.sub.4 =245 mm.

Detailed Description Text (17):
To implement a three-dimensional picture taking unit, it is necessary for the system to enable a scene to be observed from different viewpoints, there being two or more viewpoints, and for each viewpoint to be sufficiently far from the preceding viewpoint for there to be a considerable difference (or disparity) between the views. When the picture is taken using a single objective, and without moving these component elements in the plane parallel to the image plane, all of the relative displacement of the axes of the viewpoints must be contained within the horizontal diameter of the pupil of the objective which thus constitutes the total available stereoscopic baseline. In the example described above, the total stereoscopic baseline, or working horizontal diameter of the pupil is equal to 100 mm, i.e. it is greater than the distance between the pupils of an adult human (about 65 mm). In order to obtain a stereoscopic baseline of 10 cm with an objective that does not have significant defects, and for the perspective of the filmed scene to be no different from that perceived by an observer, it has been discovered experimentally that a ratio of about 2 between the focal length and the working horizontal diameter

of the pupil gives the looked-for results. This has led, in the above example, to using an objective having a lens L.sub.1 with a focal length of 200 mm for an aperture f/2.

Detailed Description Text (18):
The focal length should not be considered as such. since account must be taken of the dimensions of the sensitive surface used. For a standard tri-CCD camera provided with sensors forming a target of about 8.8 mm.times.6.6 mm, this focal length defines a very narrow object field, and indeed one that is less than one-tenth of the field (about 160 mm) provided by the "standard" focal length for such a surface (i.e. about 16 mm). The solution to this problem of reconciling an appropriate stereoscopic baseline with a standard focal length is to separate these two incompatible requirements by using an intermediate first image plane having an area that is ten times greater, for example. This area is physically embodied by a lens array having a working area of 80 mm.times.60 mm. This image is transferred by a second objective having a short focal length, e.g. 25 mm mounted on the camera so as to make the image it forms of the array coincide with the CCD charge-coupled sensors. Once the stereoscopic baseline has performed its function in forming the image on the array of vertical cylindrical lenses, it is possible to reduce the image by transferring it in air while conserving the angle of the object field.

Detailed Description Text (19):
More particularly, by using simultaneously both the objective L.sub.1, L.sub.2 which is preferably telecentric, and the dimensions by a factor of about 10 in the present example, since the working area of the first image plane is about 60 mm.times.80 mm. Since the lens array 20 is disposed substantially at the first image plane of the optical system L.sub.1, L.sub.2, this makes it possible to conserve the benefit of the 10 cm stereoscopic baseline in spite of the reduction of the image format on the sensor 22. The use of an initial area of 60 mm.times.80 mm makes it possible to combine both the field which is little greater than the standard focal length for this format (160 mm) and the large stereoscopic baseline which is equal to 10 cm.

Detailed Description Text (20):
Another advantage of the invention consists in greater ease of manufacture and of positioning of the lens array 20. It is much easier to manufacture one array, particularly when its pitch is 0-4 mm, than it is to manufacture three arrays at a pitch of 0.04 mm. It would also be extremely difficult to position three microarrays in the three CCD sensors while ensuring exact superposition of the three color images (red, green, blue) obtained in this way taking account simultaneously of the parallelism of the microlenses and of the image planes, and of the pitch and the phase of the lenses, while nevertheless conserving the functionality and the cleanness of the sensors. That could only be done by a manufacturer of camera sensors. By transferring the image in air in accordance with the invention it becomes possible to use a single array that is easily adjustable and removable, should total compatibility of equipment be desired (between taking pictures in relief and equipment as used today).

Detailed Description Text (21):
The picture-taking device of the invention makes it possible firstly to use a single array 20 for all three colors, and secondly for this array to be of large dimensions, thereby making it easier to manufacture and to position with the desired accuracy. This avoids the drawbacks both of FIG. 1 (small sized array difficult to position in the sensor, and in any event not avoiding the geometrical distortions inherent to that geometry), and of FIG. 2 (large number of lens arrays which are practically impossible to keep in alignment except under very severe experimental conditions).

Detailed Description Text (23):
Because the sensors 24, 25, and 26 of the camera operate in discrete manner, it is possible to avoid dividing the pupil into as many sub-pupils as there are selected viewpoints. While the image is being transferred, the image of the array 20 is positioned in such a manner that each image of each lens (or microimage of the pupil) is formed on an integer number of image points (or pixels) equal to the number of viewpoints. The discrete nature of the sensitive surface of CCD sensors gives rise to the first pupil of the system being rendered discrete by the

reversibility of light paths.

Detailed Description Text (24):
Because the microimages of pupil No. 1 that are formed at the location of the lens array (in the manner of a continuum) are projected onto a structure that is discrete not only in space but also with respect to energy, it is possible to subdivide the pupil into istinct geographical zones that are equal in number and in relative disposition to the pixels put into exact correspondence with the lenses of the array. In the above example, each microlens image is formed horizontally on four pixels, thereby subdividing the main pupil into four equal zones separated by portions that are made blind because they correspond to the inter-pixel gaps of CCD sensors. The horizontal structure of the selected sensitive surface determines the resulting structure of the pupil available for taking pictures in relief and consequently determines the means for processing the image obtained in this way. The fact of using four pixels per microlens leads to four viewpoints being filmed simultaneously (one viewpoint per sub-pupil). Electronic processing of the image becomes possible because the processing is performed on the smallest entity of the resulting composite image: the pixel, thus giving rise to excellent separation between the viewpoints. Permutation of pixels in columns defined by the edges of the images of the microlenses corresponds to permutation of the positions of the above-described sub-pupils.

Detailed Description Text (25):
Even better stereoscopic separation can be obtained by having the direction of the lines of the sensor 22 parallel to the axes of the lenses in the lens array 20. The separation between adjacent image points belonging to different lines is greater than that between adjacent image points belonging to the same line. This corresponds to positioning that is at 90.degree. compared with ordinary conditions (vertical line scanning), but if so desired, that can be reestablished by appropriate electronic processing.

Detailed Description Text (28):
When, by means of a diaphragm positioned in the main objective, the optical path corresponding to one of the sub-pupils is interrupted, the corresponding viewpoint on the display screen disappears. If the lens array of the camera system is observed, it can be seen that light then illuminates no more than three-fourths of each microlens, and if the CCD sensor could be observed directly, it would be seen that one pixel in four was receiving no light.

Detailed Description Text (29):
Thus, the slightest error in positioning the camera relative to the array gives rise to defects that are perfectly identifiable and reproducible in the correspondence between the array and the sensors of the camera. Such projection errors give rise to darkening defects of viewpoints in the N image mode associated with a partial diaphragm at the location of the sub-pupils. Without this mode of processing, it would be necessary to identify darkening defects on one pixel out of four and to be capable of identifying the portions of the screen where the dark pixel no longer belongs to the same series. Adjustment defects give rise to non-orthoscopic projection of the array and the resulting moire shapes are highly changeable, giving rise to moire patterns of increasing size as the lens frequency comes close to the pixel frequency divided by four (assuming only the magnification of the projection is not perfect), to trapezium shapes or to moire patterns that are curved at progressive frequencies. N image mode makes it possible to magnify the phenomenon about 200 times, so defects are observable on the scale of one-fourth of the screen rather than on pixel scale. Adjustment accuracy and repeatability becomes accessible without inspection apparatus of the kind to be found in optical laboratories. Once experience has been gained, it is easy to associate a correction in the positioning of the camera in three dimension by means of micrometer screws with defects observed macroscopically in each viewpoint by this method, so as to obtain a good spatial distribution of viewpoints on display and/or on recording. Errors of this kind cannot be put right subsequently.

Detailed Description Text (54):
The input module M3 serves to digitize the levels of the analog signals that represent the colors of each image point or pixel. The digitizing frequency is close

to 14 MHz and the resolution for each color is 8 bits. The analog-to-digital converter ADC programmed by the control module MC enables gain and black level for each color to be adjusted, with the clamping circuits for each color being incorporated in known manner in the converter (it is recalled that with standardized television transmission, e.g. SECAM, PAL, or NTSC, this is done by using levels given at the beginning of each line).

Detailed Description Text (59):
The output module MS serves to play back the color image that has been processed, either in analog form (converter DAC) or in digital form (module DT and output bus DV). The playback frequency is either the digitizing frequency or twice that frequency, giving a maximum of 30 MHz with 8-bit resolution per color.

Detailed Description Text (75):
It should be observed that the Applicant's U.S. Pat. No. 5,099,320 issued on Mar. 24, 1992 describes how to obtain an image in relief mode from cylindrical lenses that provide an image in inverted relief. That patent describes in particular the address permutations which make it possible to obtain an image in true relief.

Detailed Description Text (102):
The embodiment of FIG. 25a uses four liquid crystal video projectors 41 to 44 of the SHARP XV100 type, each of which has a resolution of 280 lines with 370 points per line in true superposed red, green, and blue colors. The image points or pixels are square in shape.

Detailed Description Text (103):
The images are projected on a frosted screen 52 through a first optical array of the type comprising vertical cylindrical lenses or of the parallax barrier type. Downstream from the screen 52, there is a second optical array of the vertical cylindrical lens type. The image is observed by the eyes of an observer 55. A description of parallax barriers can be found, in particular in the article by Ian Sexton entitled "Parallax barrier display systems", published under the reference 99/2173, in the proceedings of the colloquium on stereoscopic television held on Oct. 15, 1992 by the Institution of Electrical Engineers, London 1992.

Detailed Description Text (112):
The second optical lens array 53 located between the spectator 55 and the frosted screen 52 is selected so as to enable binocular observation of the multiplexed image, the pitch and the focal length of the array 53 being selected in such a manner that, at the selected observation distance the spectator perceives in each eye only one viewpoint (a solid color, i.e. without moire fringes), and that both eyes see two complementary viewpoints (a stereoscopic pair). The solid color obtained by this system depends on the ratio between the distance of the first projectors 41 to 44 from the first array 51 used for splitting up the image, and the choice of pitch and focal length for said array, relative to the distance between the spectator 55 and the observation array 53, and also the choice of pitch and focal length for that array. Adjustment can be performed by superposing lines of light coming from one of the projectors with lines coming from a lamp simulating one of the eyes of the observer for a given viewpoint.

Detailed Description Text (113):
The pitch of the lens arrays may be selected to be as small as possible given the graining of the frosted screen. If the pitch of the arrays is too small, then the graining of the screen gives rise to a loss of definition.

Detailed Description Text (119):
The invention is not limited to the embodiments described and shown. In particular, it may be observed that the lens array 20 acts in one direction only (horizontally). A linear object having a horizontal axis and placed at infinity gives rise to a real image in the downstream focal plane P of the array 20 (downstream in the propagation direction of the light rays). A linear object having a vertical axis placed at infinity gives a real image substantially at the focus F of the entrance objective (L.sub.1, L.sub.2) which focus F must be situated upstream from the diverging lens array 20. This gives rise to astigmatism which, in the present case, can disturb focusing, particularly on distant objects.

Detailed Description Text (120):
To compensate it, it is possible to place a diverging cylindrical lens 40 of long focal length e.g. downstream from the pupil P.sub.2 of the entrance objective, and preferably between L.sub.1 and L.sub.2, the generator lines of the diverging lens 40 being horizontal (i.e. it is crossed relative to the lens array 20 which is disposed vertically). Its focal length is calculated to move together and preferably cause to coincide the convergence point for vertical objects and the focal plane F of the diverging array.

Detailed Description Text (121):
For horizontal objects, the light rays converge on the focus F and a virtual image is formed on the plane P. For vertical objects, the cylindrical lens 51 crossed with the lens array 20 has the effect of causing real images thereof to be formed in the plane P.

Detailed Description Text (122):
Another solution is to place a second converging lens array practically in the same plane as the first, having the same focal length as the first, or a focal length calculated so that the two focal planes coincide, and whose pitch corresponds to a pixel (on one-fourth the pitch of the first array for square pixels and four viewpoints). The pupil parameters are then fixed.

Other Reference Publication (4):
M. Ueda et al. "TV Transmission of Three-Dimensional Scenes by Using Fly's Eye Lenses", Japanese Journal of Applied Physics, vol. 16, No. 7, Jul. 1977, Tokyo JP, pp. 1269-1270.

CLAIMS:

3. An apparatus according to claim 1 wherein the first cylindrical array is a lens array.